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AN ANALYSIS OF EFFICIENCY OF DRIP IRRIGATION TECHNOLOGY IN REDUCING WATER USE

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ABSTRACT

Irrigation is one of the key factors affecting the capacity of agriculture to respond to global climate change. Micro irrigation is seen as a boon for water saving by increasing water use efficiency. Micro irrigation is a method, where water is supplied directly to the root system in the form of droplets. Technical innovations appear to be efficient at theoretical and conceptual level but may lead to contradictory results in practice. More efficient irrigation technologies do not always reduce water use, some past studies show there is extension of area under irrigation with saved water. With this background, the main concern of the study is to analyse whether the intervention of drip irrigation technology has reduced the water used in farms. Testing of Jevons Paradox was attempted in the study. The results indicate that in the study area the water used per farm in acre inches is reduced when the area is irrigated through the drip technology.

KEYWORDS: Groundwater Extraction, Drip Irrigation & Jevons Paradox

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Original Article

INTRODUCTION

Groundwater is the world's most extracted raw material with withdrawal rate of 92 km^3/year. India alone extracts a world–record breaking of groundwater abstraction of 251 m^3/year according to the groundwater abstraction 2010 (National Groundwater Association, 2013). About 60% of groundwater withdrawn worldwide is used for agriculture, the rest is divided between the domestic and industrial sectors. Globally, about 38 % of irrigated lands are equipped with groundwater for irrigation. Irrigation is one of the major factors influencing agriculture's capacity to adapt to global climate change. The greater variability in rainfall increased average temperature and severity of droughts has made agriculture production more dependent on irrigation.

Micro irrigation is seen as a boon for water saving by increasing water use efficiency. Micro irrigation is a method, where water is supplied directly to the root system in the form of droplets. Sprinkler and drip are the main elements of micro irrigation that have been operating in Indian irrigation sector. In addition, having high water-use efficiency, the technologies increase crop yield at reduced cost of cultivation compared to conventional irrigation methods such as flood irrigation or any other surface irrigation measures.

Noticeable growth of area under micro irrigation has taken place in India (Narayanamoorthy, 2004). In addition, appreciable growth of area under micro irrigation is noticeable since after 2005. The area has increased from 3.09 million hectare in 2005 to 7.73 million hectares in 2015 at the rate of 9.6%. However, the country's penetration in micro irrigation technologies was 5.5% less than the rest of the world such as Israel, USA, Russia, Spain and China (Balyan 2016).

Drip irrigation technology has been documented to increase water use efficiency with about 40 to 80% and to be responsible for increased yield levels, reduced tillage requirements compared to other irrigation methods (Sivanappan, 1994). A study on comparative analysis of drip and flood irrigation methods analyzed under field experiments indicated that more efficient use of water generates higher crop yield under drip condition (Erankia *et. al*., 2017). Drip irrigation requires less energy and reduced water consumption as compared to flood irrigation (Narayanmoorthy, 2008). Farmers are able to extend the irrigated area under drip irrigation with the same amount of water used for the flood method (Narayanmoorthy, 2008). Extension of irrigated area yield more income to cover the initial investment cost (Reddy, 2016).

JEVONS PARADOX AND ITS RELAVANCE TO THE STUDY

The rebound effect of technology can be interpreted as if the efficiency increased by ‘x’% then the resource consumption may increase or decrease by ‘x’%. For example, energy efficiency increased by 6%, which led to an increase in energy consumption by 4% (Yorka & McGeeb, 2015). This is termed as rebound effect. Furthermore, rebound effect of technological efficiency will lead to counterproductive results of the technology’s real purpose. This is called Jevons Paradox.

Drip irrigation is operating as a technological invention in the field of agriculture, preferably in irrigation. On the one hand, world population is growing rapidly and on the other hand, food demand is also increasing at a fast rate (FAO, 2009). Thus, irrigation is important to fulfill not only food demand but many other requirements as well since water is a basic necessity for all. Government of India is promoting the technology with the goal to increase water use efficiency, as it saves water by reducing quantity to be consumed. Finally, it leads to water conservation, as India is a water-stressed country, being the second largest populated country in the world (Seckler *et al*., 1999). Irrigation is an important tool to address food security of the country. However, some studies on irrigation modernization showed that irrigation modernization and technology adoption sometimes lead to rebound effect by increasing consumption of water, which happened in the case of western Kansas (Pfeiffer & Cynthia, 2013). Furthermore, in California, the state subsidized to convert traditional irrigation system in to efficient irrigation (nozzle drippers) technologies because of depletion in groundwater table, but the technology effect was negative because farmers ended up increasing more area under irrigation with groundwater (Cynthia, 2013). In Morocco, a study on three cases of drip irrigation adoption indicated that water and energy efficiency did not lead to water saving rather it results in water extraction (Guy, *et al*., 2015).

Technical innovations appear to be efficient at theoretical and conceptual level but may lead to contradictory results in practice. In addition, water-efficient innovations and water saving may not go hand in hand. Moreover, if extension of area under irrigation is with saved water, then it will lead to unsustainable use of groundwater and make the technology inefficient to serve its purpose. More effective systems, however, do not always minimize the use of irrigation water. With this background, the main concern of the study is to analyse whether the intervention of drip irrigation technology on farm has led to the expansion of irrigated area on farms rather than water conservation.

MATERIALS & METHODS

Coimbatore district in Tamil Nadu has been purposively selected for the study on the basis of comparatively high percentage of area irrigated by wells accounting for about 70% of total area irrigated. Dug wells and borewells are the most common groundwater abstraction structures used for irrigation in the district. The next stage was to select the blocks in Coimbatore district. All the blocks in the district were classified based on their groundwater resource potential and their

stage of development (level of exploitation). The blocks Annur and Karamadai, which were overexploited and safe, respectively, were selected for the study.

TESTING JEVON'S PARADOX ON DRIP IRRIGATION FARMS

The present study tests Jevons Paradox through regressing groundwater used per farm as a function of gross irrigated area, drip adoption and the interaction of these two variables.

$$\mathbf{Y = \beta_0 + \beta_1 GIA + \beta_2 DRIP + \beta_3 DRIP*GIA + \varepsilon,}$$

where Y represents the groundwater used per farm in acre inches.

GIA represents the gross irrigated area per farm in acres per year.

DRIP represents dummy variable for drip technology.

DRIP *GIA represents the interaction dummy variable representing interaction between gross irrigated area and the technology of drip irrigation. The coefficient β_3 captures the rate of increase in use of groundwater on drip irrigation farms due to increase in gross irrigated area resulting in extensive cultivation, if any.

ε: represents stochastic error term.

RESULTS AND DISCUSSIONS

Cropping Pattern in Sample Farm Households

Cropping pattern is one of the important indicators as well as determinants of water availability and water utilization at farm level. Climate change has adversely affected crop yields in recent decades, as well as the cropping pattern in certain regions, by affecting agricultural inputs such as irrigation water, as well as its effect on pest and disease prevalence. These impacts vary significantly according to whether crops are rainfed or irrigated. Cropping pattern with water-intensive crops is largely responsible for overexploitation of groundwater, especially if they are cultivated during the dry spell of the year.

Table 1: Cropping Pattern Followed by Sample Farmers in Karamadai Block

Sl. No.	Particulars	Annur Area (ha)	Karamadai Area (ha)
1	**Banana**	39.2 (41.44)	46.8 (42.94)
2	**Turmeric**	9.4 (9.94)	4.8 (4.40)
3	**Tobacco**	5.4 (5.71)	2.4 (2.20)
4	**Sugarcane**	3.2 (3.38)	1.2 (1.10)
5	**Jathimullai**	3.4 (3.59)	10.2 (9.36)
6	**Brinjal**	6.4 (6.77)	16.2 (14.86)
7	**Small onion**	1.4 (1.48)	5.2 (4.77)
8	**Curry leaves**	4 (4.23)	11.4 (10.46)
9	**Maize**	17 (17.97)	6.2 (5.69)

10	**Tomato**	5.2 (5.49)	4.6 (4.22)
	Gross cropped Area	94.6 (100.00)	109 (100.00)

(Numbers in Parenthesis indicate percentage to total)

The total gross cropped area was 204.6 ha, of which 109 ha cultivated in Karamadai block and 94.6 ha in Annur block. Around 40% of the farmers cultivated banana in 80 ha, followed by 14.2 of turmeric and 7.8 ha of tobacco. Vegetable crops like tomato, brinjal, chilly, small onion and curry leaves were also cultivated in notable areas. The figures. 1(a) and 1(b) show the various major crops cultivated in the area and the area of the crop under drip irrigation. In the study area, banana crop is cultivated in a larger area.

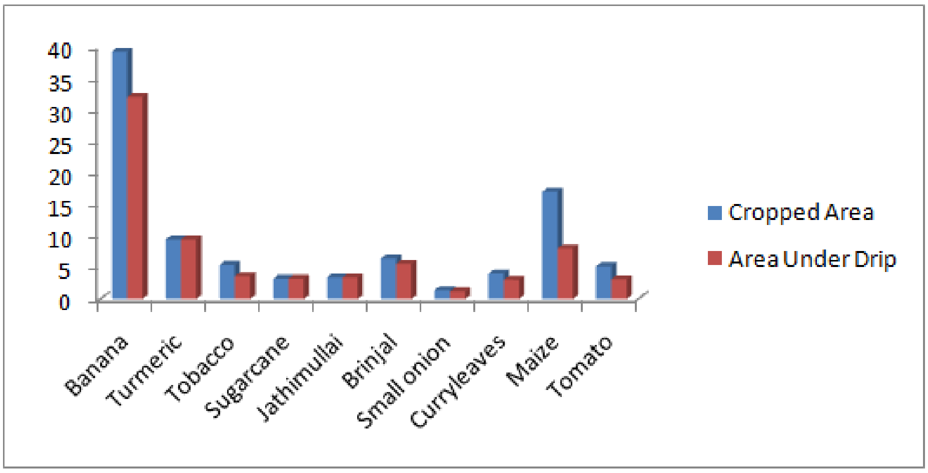

Figure 1(a)

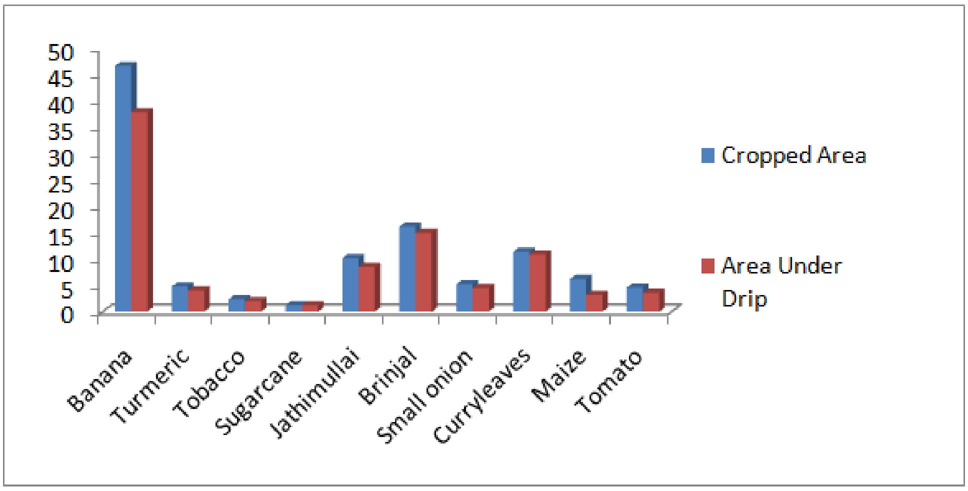

Figure 1(b)

The other crops are turmeric, tobacco, sugarcane, jathimullai, brinjal, small onion, curry leaves, maize and tomato. In both the blocks, banana is the major crop and nearly 80% of the crop is under drip irrigation. The sugarcane is completely irrigated through the drip irrigation technology. All other crops other than maize are almost irrigated through drip irrigation technology. Only in maize crop, the area under drip irrigation method is only 50%.

ESTIMATION OF JEVONS PARADOX IN DRIP IRRIGATION

For every acre, increase in gross area irrigated on drip irrigation farms, the water use reduction was the hypothesis tested. Jevons Paradox was tested by regressing the groundwater used per farm against the independent variables' drip adoption, gross irrigated area and their interaction dummy.

Table 2: Testing Jevons Paradox in Drip Irrigation (Dependent Variable: Water used Per Farm in Acre Inches)

Particulars	Overexploited Block	Underexploited Block	Total Sample
Intercept	3.39 (17.05)	2.70 (7.21)	3.27 (17.49)
Gross irrigated area in acres (GIA)	7.35* (6.74)	11.64* (5.40)	8.53* (7.83)
Dummy for Drip technology (DRIP)	0.19 (0.74)	0.29* (3.09)	0.25 (1.13)
Interaction dummy (DRIP*GIA)	-3.16 ** (-1.98)	-0.54 (-1.64)	-1.28 (-1.43)
Adjusted R Square	0.54	0.57	0.55
F statistic	32.31	37.29	66.6

Note: Figures in the parentheses indicate t value
**Indicates 5% level of significance of the estimates
*Indicates 1% level of significance of the estimates

It is revealed from the table that the gross irrigated area significantly influences the water used per farm. The results indicate that for every acre increase in area, the water increases by 8.53-acre inches in the study area. The drip technology increases the water use in both the block in very meager measures and not to a noted extent. The interaction term influences the water use negatively, which indicates that the water use is reduced when the gross area is irrigated through drip irrigation technology. The water use is reduced by 1.28-acre inches for every acre increase in the gross area irrigated on the drip-irrigated farms. The water use reduction is highly influential through the drip technology in the underexploited block Karamadai than in Annur, the overexploited block.

CONCLUSIONS

Micro irrigation is a noticeable innovation in the field of irrigation, preferably for the water-stressed and heavily populated countries such as India, China and other economies. However, the achievement of micro irrigation area in India is less compared to the other countries like Israel, USA, Spain, Russia and others. However, the continuous effort to promote technologies is under process.

The main agenda of micro irrigation is "more crops per drop". In India, drip irrigation method has wider adoption among various methods of micro irrigation. These methods not only reduce water consumption or increase water use efficiency, but also lower labor requirement, increase productivity and the net returns of the crop cultivation.

The study proved that drip irrigation is reducing the water consumption for crop cultivation compared to flood or conventional irrigation. Though drip irrigation is saving water in the study, area under irrigation is more for plantation, vegetable and commercial crops than food crops. It is necessary to organize extension training programs to farmers for reaching the drip technology's main objective and providing subsidies to conserve water and not to increase farmer's profit in the study area.

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